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New Innovations in Thermal Storage

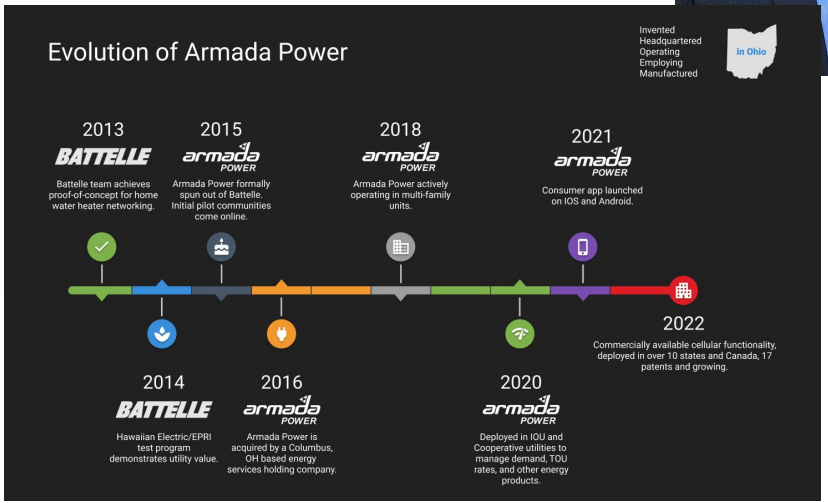
Maximizing the Benefits of Non-Traditional Storage

Speaker Intro

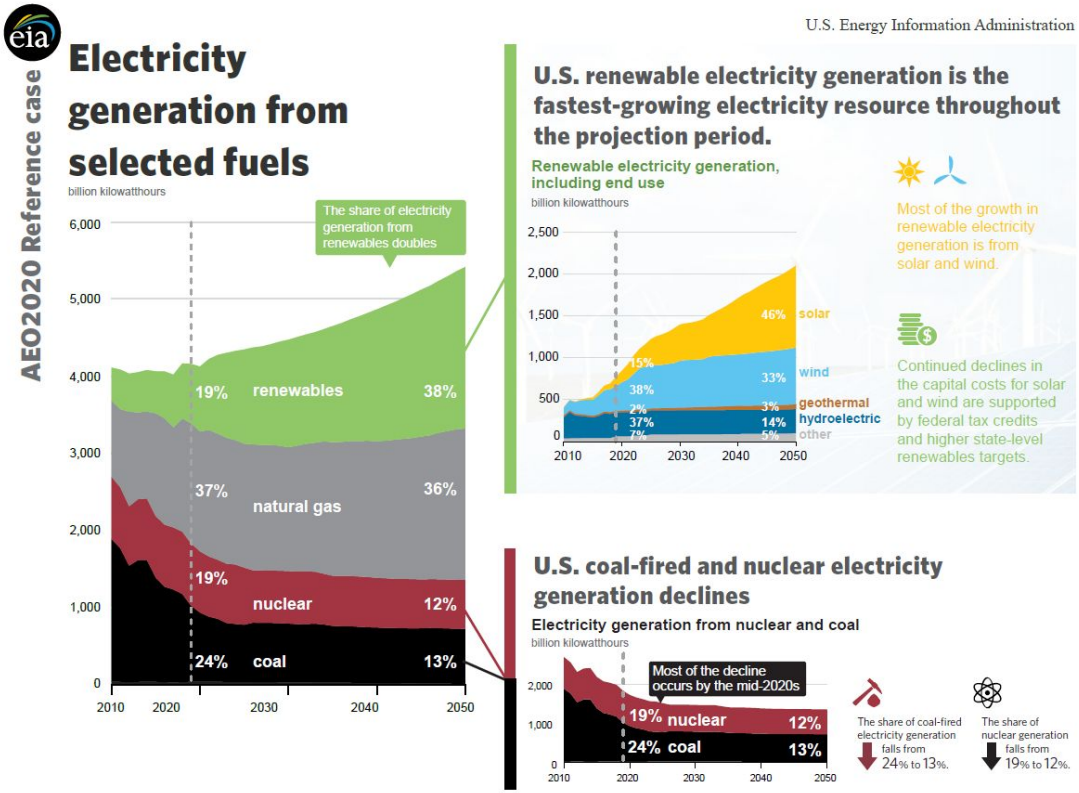
Eric Rehberg

Chief Engineer, Armada Power

- 18+ years energy industry experience
- 15 patents
- American Electric Power - R&D Engineer
- Battelle Memorial Institute - Principal Engineer
- Licensed professional engineer in the State of Ohio
- The Ohio State University: BS in Electrical and Computer Engineering



Generation Landscape Changing Fast



The need for low-cost energy storage to support renewables is growing

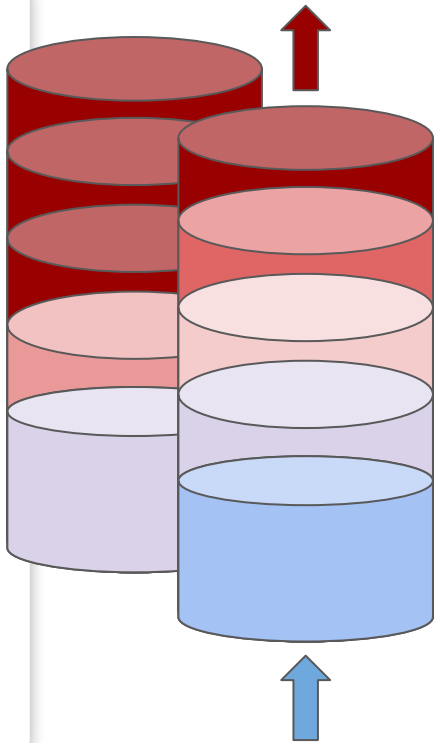
- The deployment of low-cost energy storage will increase the rate of renewables adoption - further increasing the need for low-cost storage
- Maximizing thermal storage along with electrochemical batteries creates hybrid benefits
- Flexibility to support different regulatory models is key

Thermal Storage - storage not a battery

- Using excess electricity for heating or cooling is the historic view of thermal storage.
- However, new technologies allow for thermal storage to be used for grid purposes.
  - Water heaters with **milisecond control**
  - Cold storage (Ice Energy)
  - Pre-heating with solar
- Lowest cost way to store energy
  - Use stored energy without conversion losses

Why Water Heating?

- Second largest residential load
  - 17% household energy use[1]
- Underutilized existing asset
  - 40M+ electric WH in US[1]
- Universal demographics
  - Large homes and 1 bed apartments both need hot water
- Non-invasive control (people don't notice)
- Fast millisecond response time



[1] U.S. Dept of Energy

Optimize and Increase Participation Beyond Smart Thermostats

FOR ENERGY STORAGE, JUST ONE WATER TANK OUTPERFORMS THE SMART THERMOSTATS OF UP TO 10 HOUSES.

Armada Power's solution avoids high-carbon generation sources in real time by soaking up excess renewable energy on the grid and storing it as hot water for later use. This effectively transforms the second largest residential energy load into a zero-carbon storage asset.

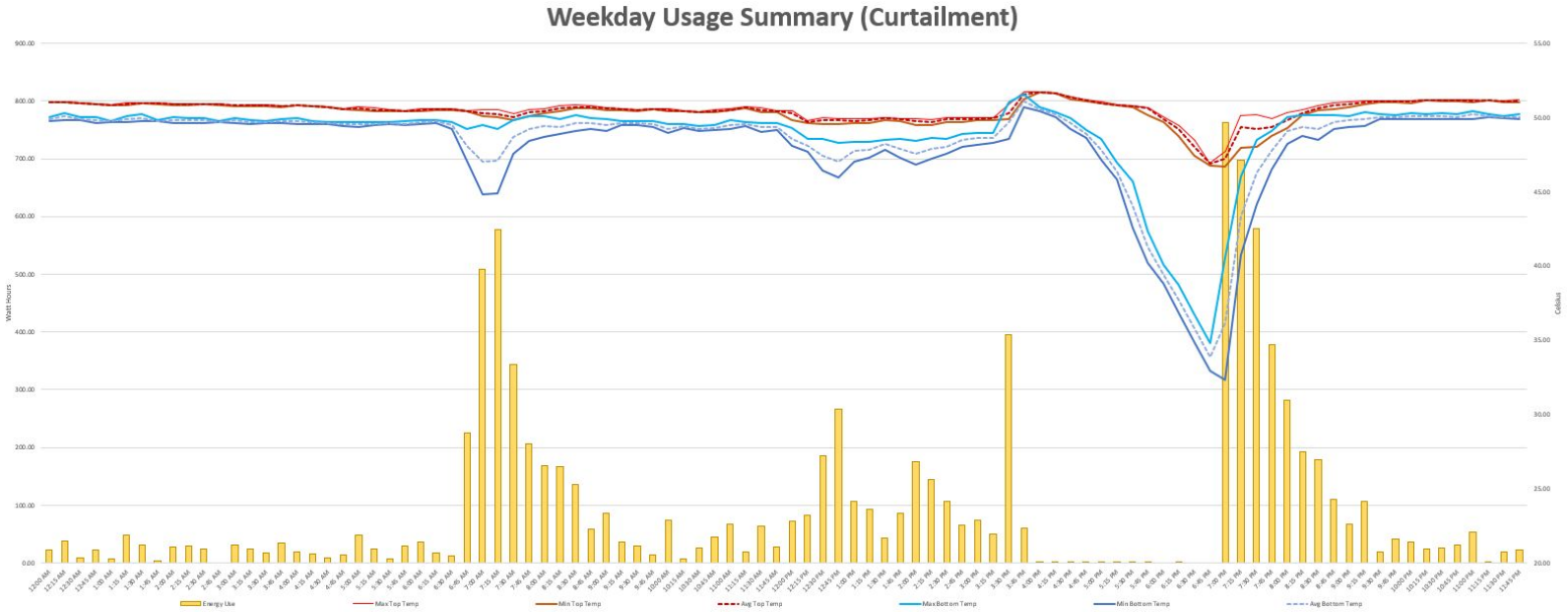
This means the energy savings produced by reducing just one 40-gallon water tank by 10°F (barely noticeable to a consumer) is equivalent to adjusting the temperature of 10 houses by 5°F (extremely noticeable to a consumer).

1 Water Tank (40-gallons) OUTPERFORMS **10 Full-House HVAC Systems** (1,350 sq. ft/each)

- Water has 3000 times the specific heat by volume
- Normal variations in water temperature are not noticed by end users
- 5°F variations in air temperature may trigger customer opt-out

0.5 to 1 kW of dependable demand management **per water heater** with no impact to customer comfort with normal usage profile

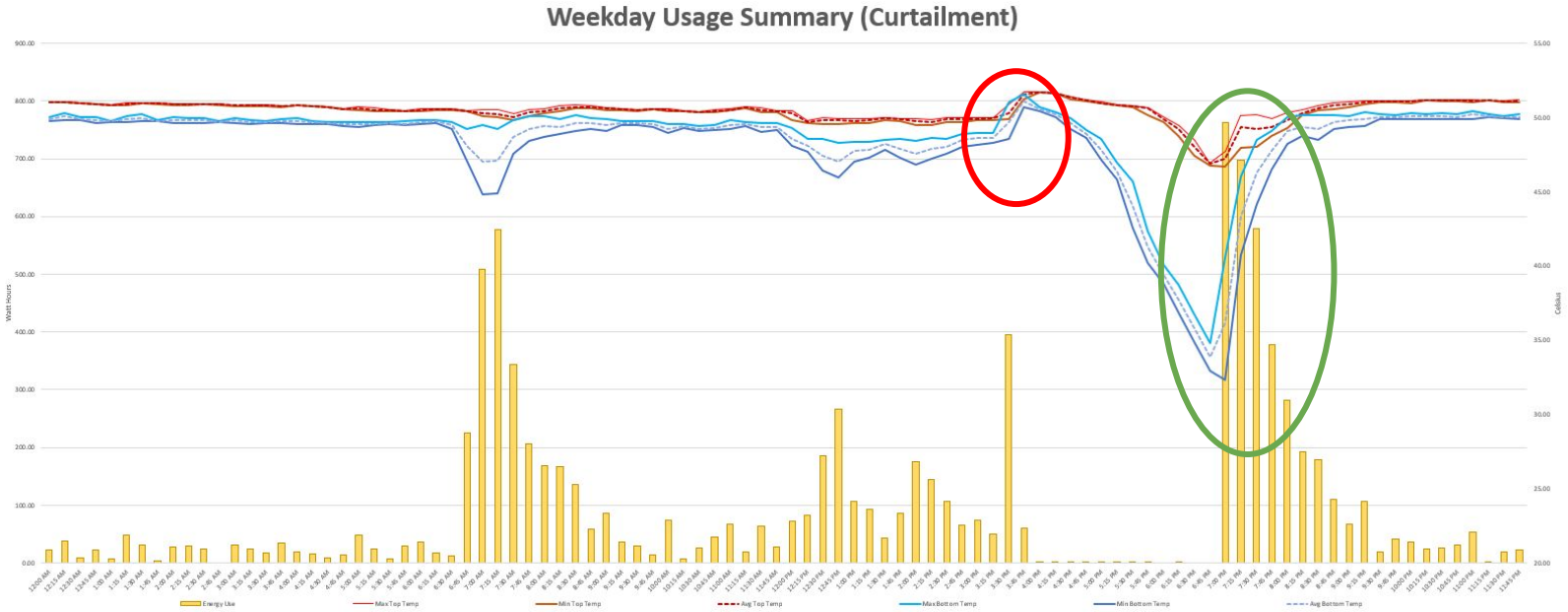
Daily Peak Avoidance Example



Demonstrated 3 and 4 hour TOU peak avoidance windows

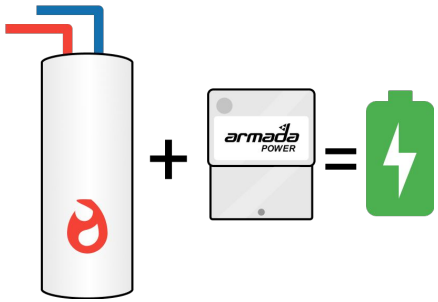
Combined with DR events as needed

Tank Optimizations

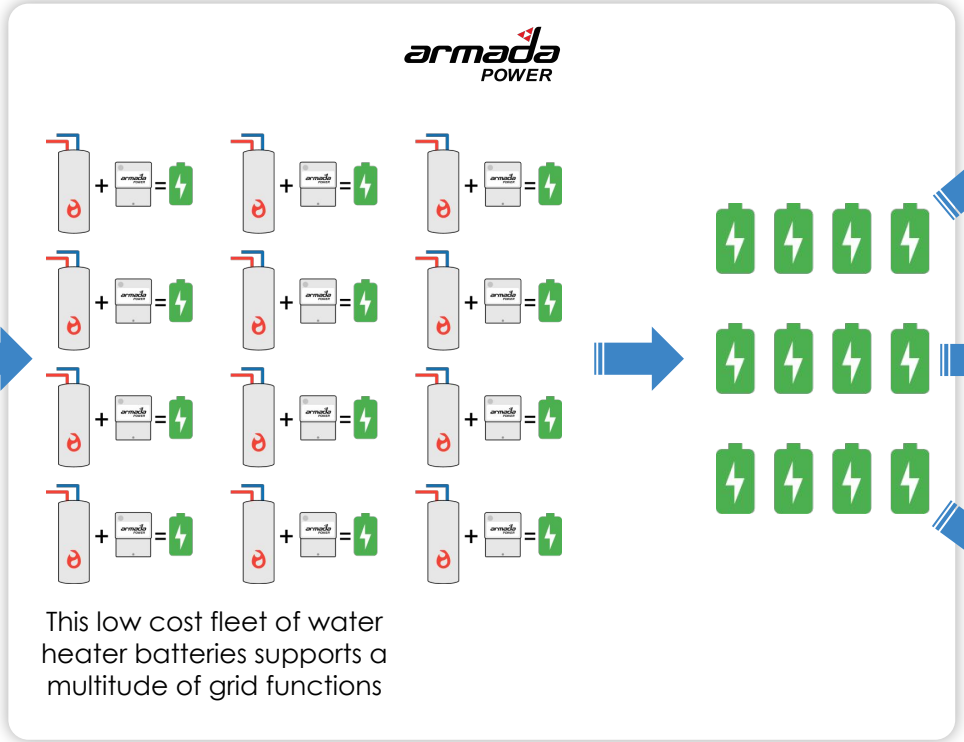


- Preheat to top of mechanical thermostat limit
- Fleet level rebound control to avoid setting later peak

Fleets of Water Heaters are Grid Resources

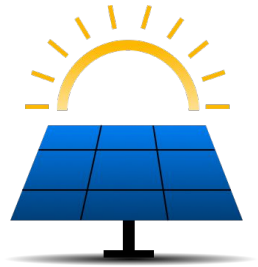


Armada Power Technology turns simple water heaters into grid batteries



This low cost fleet of water heater batteries supports a multitude of grid functions

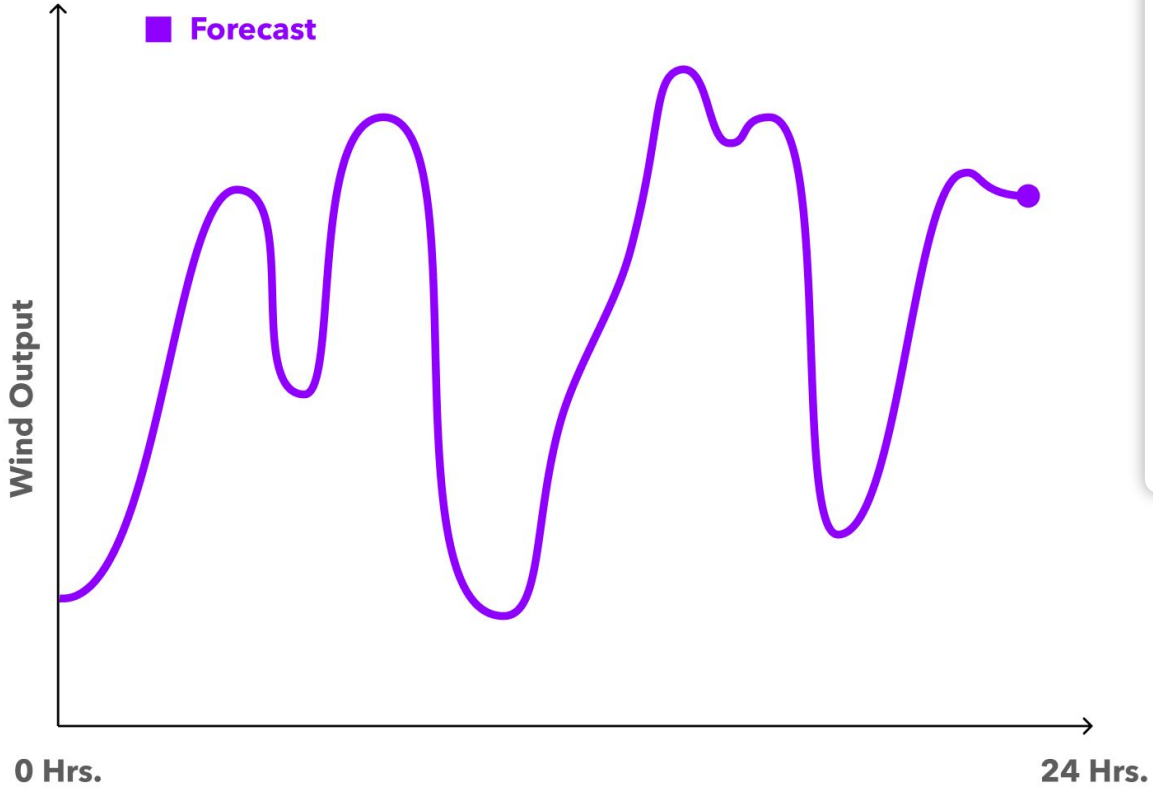
Support aging infrastructure



Increase renewable generation

Greater grid reliability

Wind Firming Example



- Wind output varies throughout the day
- The output is generally predictable on a large scale
- Historically, dispatchable fossil fuel generation is used to make up the gaps

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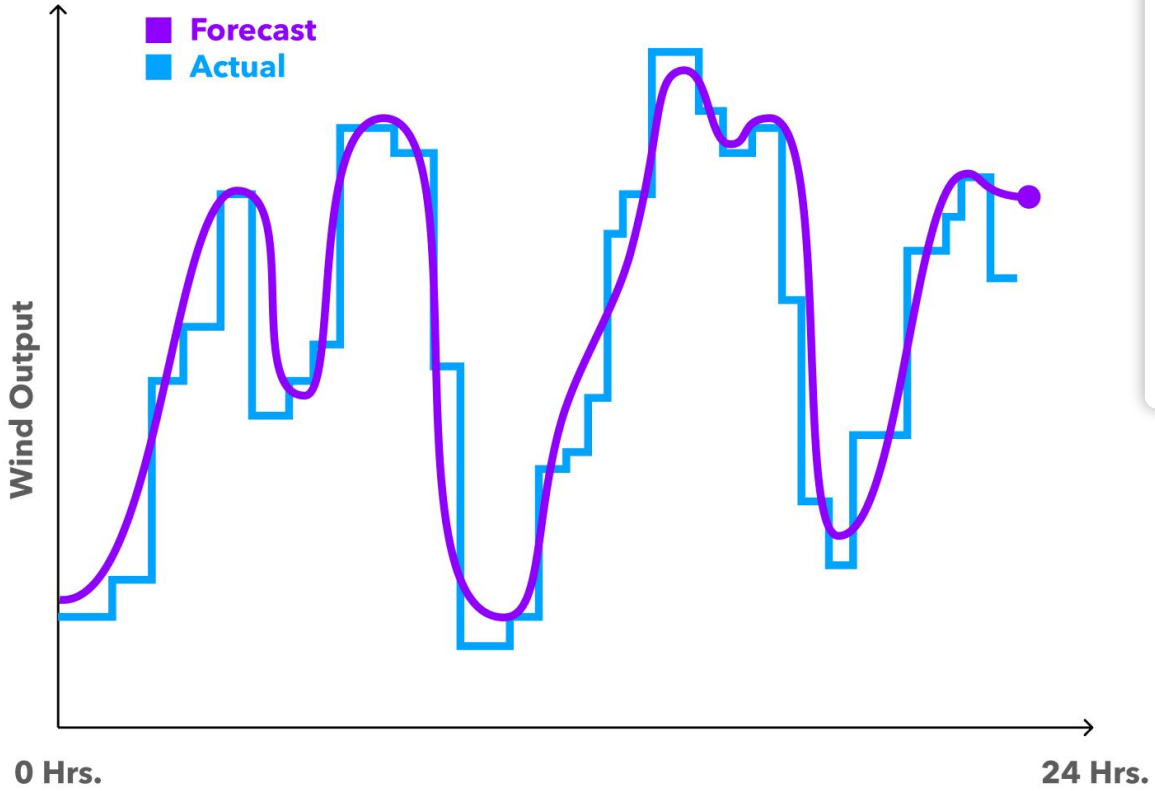
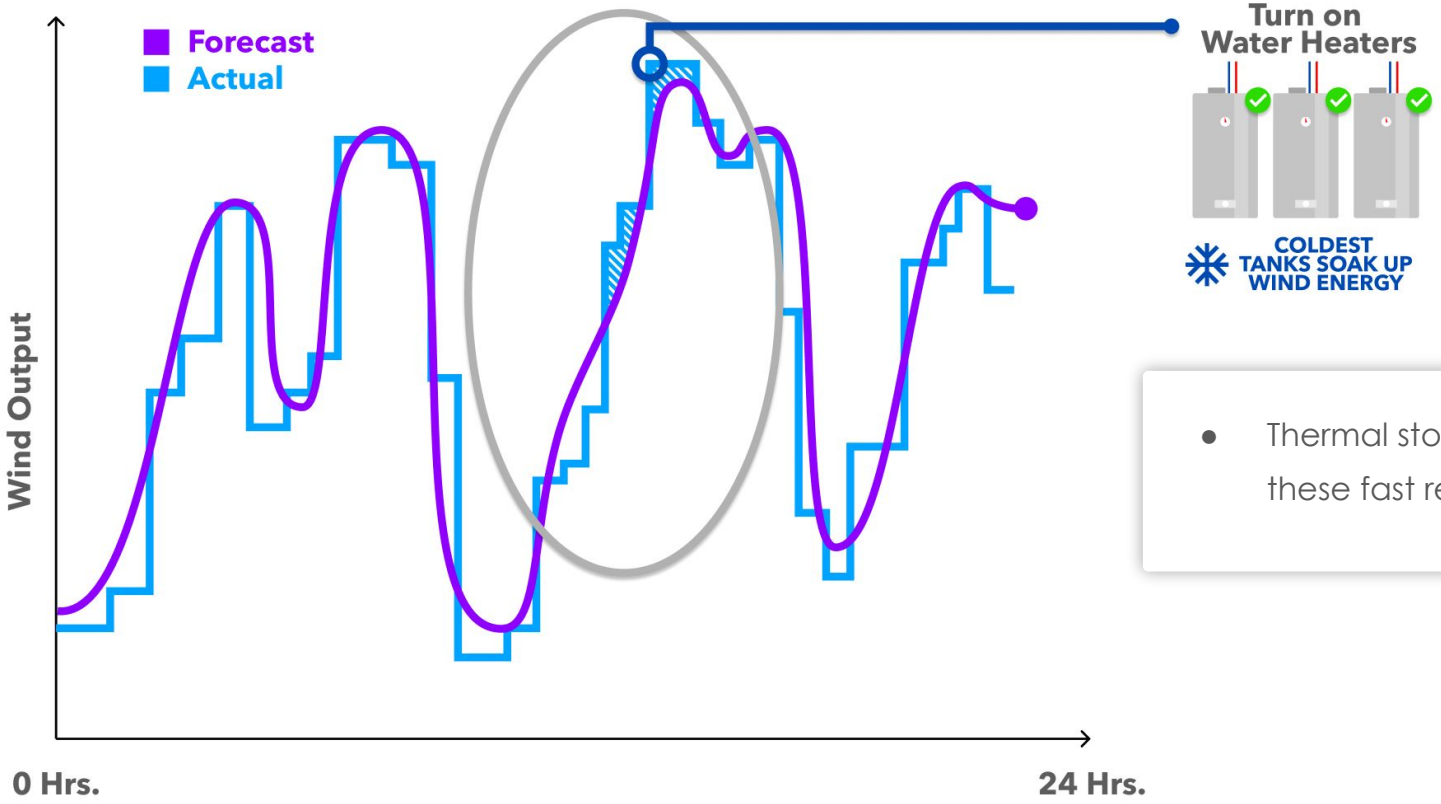
Wind Firming Example



- Some small constant variation between actual wind output and forecast always exists
- Variations can be large or small
- Fast and unpredictable

Wind Firming Example



- Thermal storage is ideal to soak up these fast responding changes

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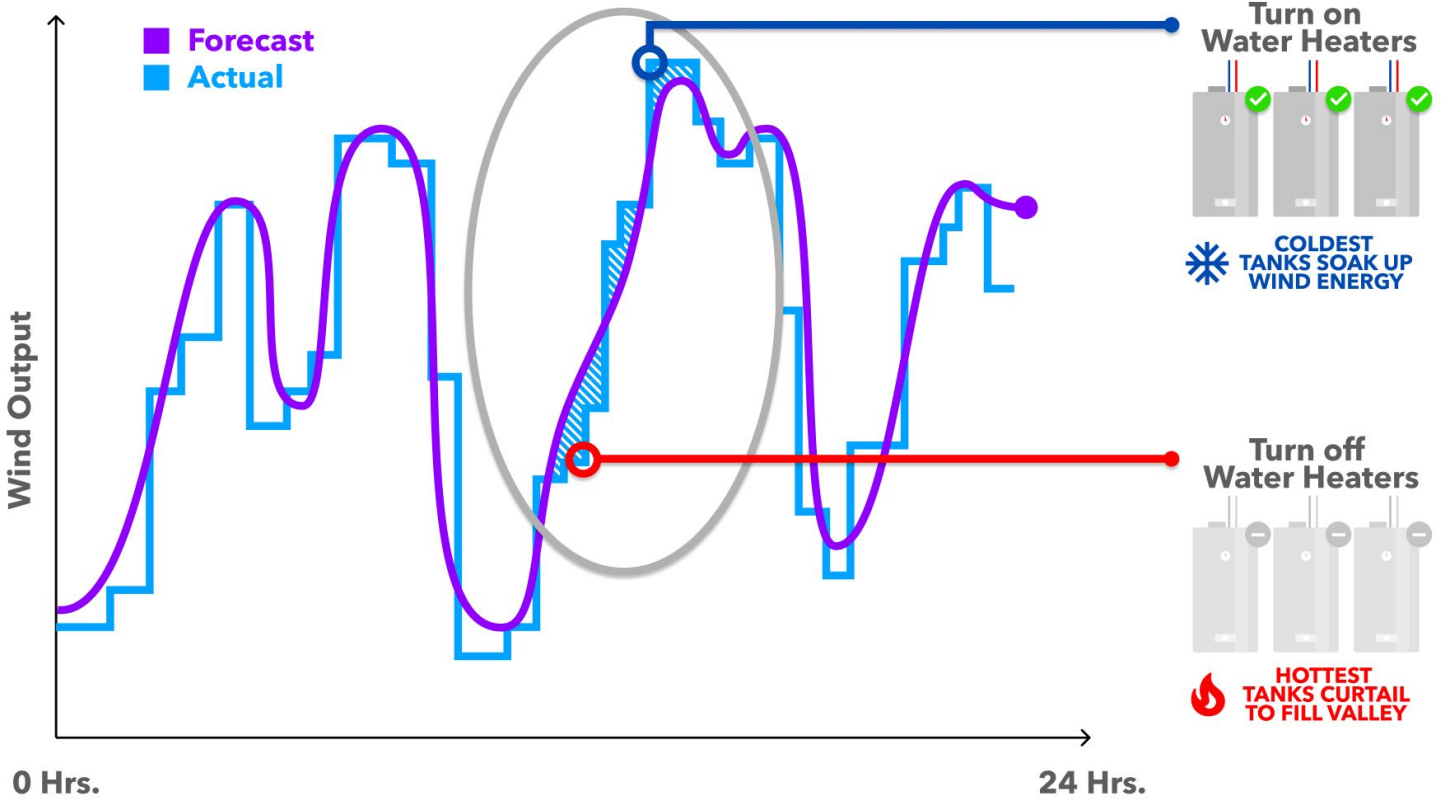

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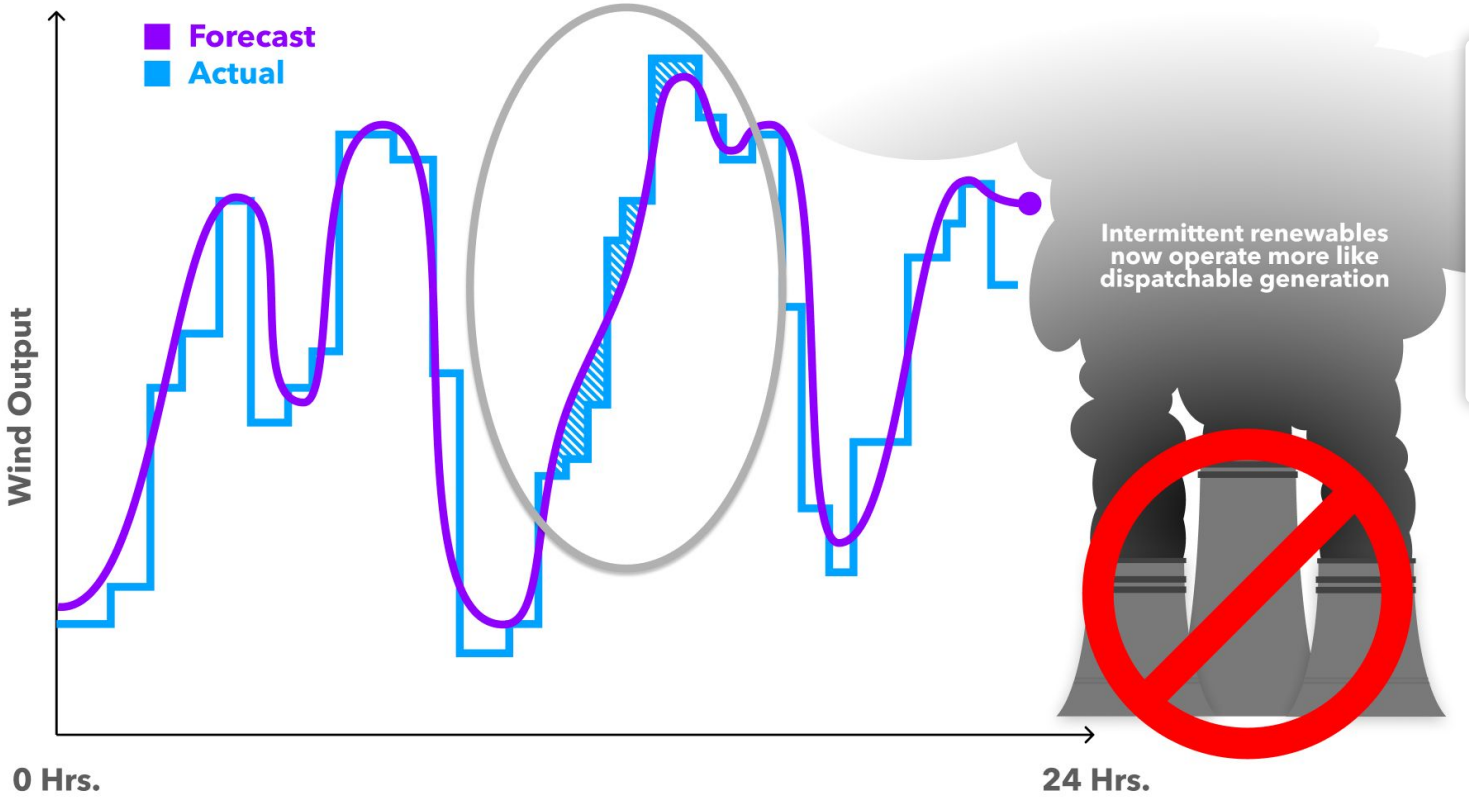


- Dispatchable thermal storage makes load follow generation

Grid Scale Impacts

Storage covers a broad value stack:

- Demand Response
- Time of Use Optimization
- Fast Frequency Regulation
- Renewables Integration
- Cold Load Pickup
- Droop Control
- Local Voltage Response

- Solar sponging
- Extends battery life
- Hybrid system of thermal plus electrochemical storage can enable new grid applications

Considerations for a good thermal storage program

Strong cybersecurity countermeasures

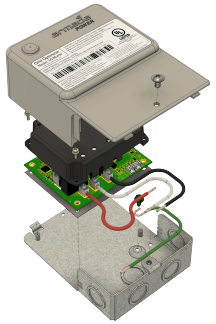
Quality data for measurement and verification (revenue grade)

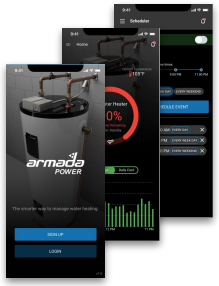
Algorithms and sensors to preserve customer comfort

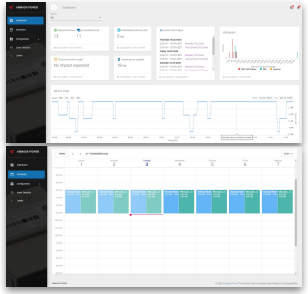
Utility grade hardware with long life components

Utility control of alternative storage versus a battery - is the storage there when it is needed?

Can fast responding thermal storage be used to augment batteries and extend the battery life?





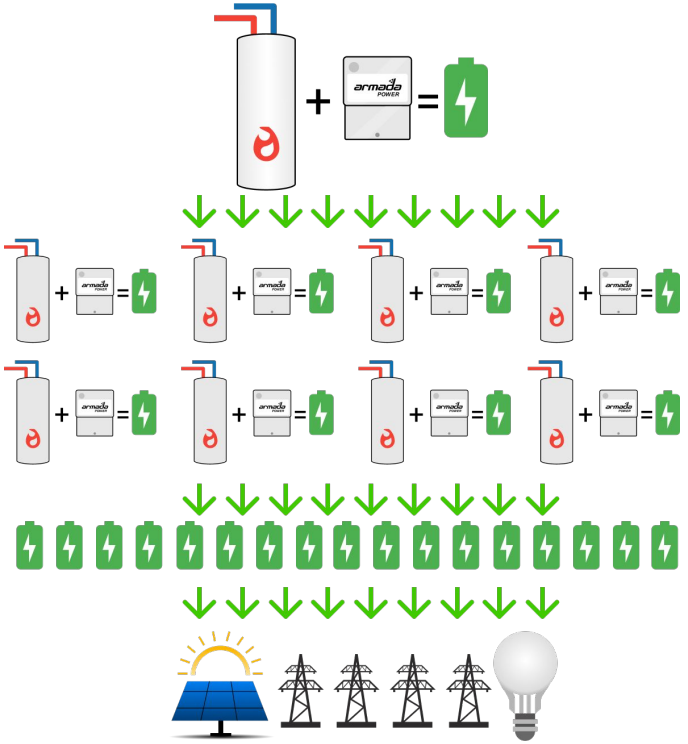


Barriers and Solutions

- **Barriers**:
  - Behind the meter technologies face unnecessary restrictions to enter the market
  - Utility account numbers required to register locations
  - Large minimum participation size per account (100 kW+)
  - Programs originally designed to only support C&I
- **Solutions**:
  - Allow aggregations of residential loads (revenue grade metering and authenticated data)
  - Allow auto enrollment processes to **streamline customer opt in**
  - Open the door to renters by enabling a landlord portal where opt in can be included with lease

Final Points

- An all renewable grid is going to need storage - a lot of storage
- Batteries are going to be key, but they could use some help with controllable load
- Thermal storage options like water heaters are an excellent controllable load
- Controls need to be secure, verifiable, and comfortable for end users
- Remove barriers to residential aggregation



THANK YOU
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